BBC RD 1974/33

1969 1974
THE QUEEN'S AWARD TO INDUSTRY

RESEARCH DEPARTMENT

REPORT

UHF TELEVISION:
requirements for long-term and short-period carrier drive frequency stability

R.V. Harvey, B.Sc., M.I.E.E

Research Department, Engineering Division
THE BRITISH BROADCASTING CORPORATION

September 1974

BBC RD 1974/33
UDC 621.391.837.41
621.397.132

UHF TELEVISION: REQUIREMENTS FOR LONG-TERM AND SHORT-PERIOD CARRIER DRIVE FREQUENCY STABILITY

R.V. Harvey, B.Sc., M.I.E.E.

Summary

The frequency stability required for the carrier drives of a group of co-channel television transmitters is examined theoretically. An upper limit is suggested for the permissible levels of long-term frequency drift and of frequency modulation uncorrelated with the video waveform. This takes into account both protection against co-channel interference and impairment of the received picture in the absence of interference. Also considered are the requirements of the inter-carrier sound signals where the sound and vision carrier drives are separate.

The results are given for both nominal and precision offset working.

Issued under the authority of

P. Rainger

Head of Research Department

Research Department, Engineering Division,
BRITISH BROADCASTING CORPORATION

September 1974
(EL-96)

UHF TELEVISION: REQUIREMENTS FOR LONG-TERM AND SHORT-PERIOD CARRIER DRIVE FREQUENCY STABILITY

Section | Title | Page

Summary .... Title Page

1. Introduction 1

2. Requirements for short-period stability 1

2.1 Picture protection 1
2.2 Sound protection 2

3. Conclusions 3

4. References 3

Appendix 1 3

Appendix 2 4

UHF TELEVISION: REQUIREMENTS FOR LONG-TERM AND SHORT-PERIOD CARRIER DRIVE FREQUENCY STABILITY

R.V. Harvey, B.Sc., M.I.E.E.

1. Introduction

System I television transmissions in the UK have carrier frequencies which are maintained within ±500 Hz of either the nominal carrier frequency or one offset by $\pm\frac{5}{3}$ line frequency (approx. ±26·0 kHz). For this nominal stability, the CCIR[1] recommends a protection ratio against tropospheric co-channel interference at $\frac{5}{3}$ line offset of 30 dB and indicates that this may be reduced to 22 dB if each transmitter has a 'precision-offset' stability of ±1 Hz. Brown[2,3] has suggested, however, that the protection ratio for precision-offset working should be 24 dB, even when the carrier-frequency stability is ±1 Hz. From the work of Hopf,[4] the frequency stability should be ± 1·25 Hz in order to ensure that the protection ratio does not rise by more than 1 dB above the precision-best value.

These protection ratios apply to carrier frequencies which are within tolerance on the assumption that the frequencies are constant during an assessment. However, a specification has not yet been agreed which describes precisely how the frequency may be permitted to fluctuate on a short-term basis, that is to say what degree of frequency modulation or phase flutter can be allowed, bearing in mind that these may affect not only the visibility of interference but also reception in the absence of interference, and that some domestic receivers may use quasi-synchronous demodulators.

This report is concerned only with phase modulation produced in the carrier drive unit (e.g. a frequency-synthesiser) before picture-modulation is applied, not with picture-correlated phase perturbations which may occur in signal amplifiers and modulators.

2. Requirements for short-period stability

It is possible for short-period fluctuations in carrier frequency, which may be caused within the vision-carrier drive unit, to be intolerably large without the frequency averaged over a short time being outside the presently specified tolerance. A specification covering short-period fluctuations is therefore desirable:–

(i) to cover existing practice with nominal (±500 Hz) stability

(ii) to cover requirements with precision stability (±1·25 Hz)

(iii) to protect inter-carrier sound reception from impairment by audio-frequency fluctuations in the case of separate vision-carrier and sound-carrier drives.

Figure 1 gives suggested curves for the maximum permissible peak deviation of the transmitter frequency as a function of modulation frequency for the latter three conditions. These curves will be discussed in detail with regard to picture and sound quality respectively.

2.1 Picture protection

Figure 1 curve (a) refers to the precision stability condition; the values which it indicates for the maximum allowable frequency deviation are supported partly by observations and partly by theory, as given in the following paragraphs.

Considering first the condition of co-channel interference from another transmission having a relative frequency offset of (n $\pm\frac{1}{3}$) line frequency where n is a small integer, there is an interference pattern containing about 100 horizontal light and dark bars which are easily visible when they are nearly stationary. If the transmissions each have precision stability and if the offset frequency is arranged to be exactly an odd multiple of half the field frequency ('precision best'), then the bar pattern alternates in phase on succeeding interlaced fields and is least visible, requiring a protection ratio some 8 to 14 dB less than that of the stationary pattern.[1] The required ratio will increase by no more than 1 dB if the offset frequency remains within ±2·5 Hz of the optimum condition. For this to apply, each transmission must have the stability of ±1·25 Hz as mentioned in Section 1. This determines the tolerance at the low-frequency end of curve (a) in Figure 1. A frequency deviation of ±1·25 Hz would be expected to be the allowable maximum at modulation frequencies of up to about 10 Hz.

To assist in determining the permissible levels of frequency or phase modulation at frequencies between 25 Hz and 10 kHz, some experimental evidence is available from work done in France.[5,6] Reference 5 describes tests carried out to assess the peak frequency deviation of the interfering carrier that gave a perceptible increase in the required protection ratio in a precision (n $\pm\frac{1}{3}$) line-offset situation with a wanted-to-interfering-carrier ratio of 22 dB. The results obtained are shown in curve (c) of Figure 1. Reference 6 describes other tests made with similar conditions and yielding somewhat different results, shown in Figure 1 as curve (d).

The permissible levels of phase modulation shown in these two curves differ by some 10 dB over most of their frequency range. The central portion of the suggested limit curve has been drawn to coincide with curve (c) for reasons which are discussed in Appendix 1.

Although the above-mentioned theoretical support for the middle section of curve (a) of Figure 1 is restricted to the precision (n $\pm\frac{1}{3}$) line offset situation, no more

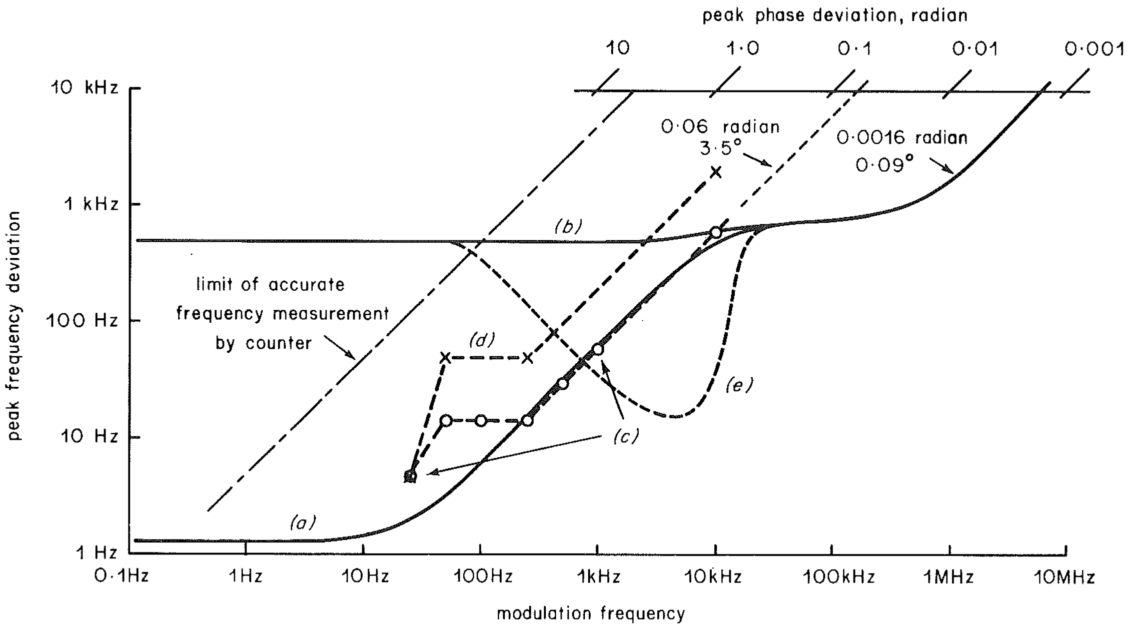

Fig. 1 - Suggested limits for frequency modulation of carrier drive for Standard I transmissions using nominal and precision offsets

(a) ———— *precision stability ± 1·25 Hz* *(b)* ———— *nominal stability ± 500 Hz*

(c) 0 - - - - - - 0 *precision stability (Reference 5)* *(d)* X - - - - - - X *precision stability (Reference 6)*

(e) - - - - - - - - *additional limitation for separate sound and vision drives*

stringent requirements are expected of precision zero-offset working.

For a nominal tolerance of ±500 Hz, no relaxation is shown in Figure 1(b) for phase deviation at modulation frequencies of up to 10 kHz although, in general, a phase perturbation would tend to reduce the pattern visibility and allow a relaxation for the same protection ratio. It has in fact been suggested[7] that the protection ratio for nominal offsets could be reduced by introducing a particular form of phase jitter in the drive unit.

A theoretical consideration of the effects of frequency modulation of the wanted signal at modulation frequencies higher than 10 kHz suggests that this should be limited to a peak deviation of 0·8 kHz in order to prevent the amplitude modulation, which is caused by the asymmetry of the receiver v.s.b. characteristic, from impairing the picture (see Appendix 2). Above about 1 MHz the asymmetry is complete and the peak phase deviation should then be limited to about 0.0016 radian, as shown by Figure 1, curve (a). With this limitation, the picture impairment caused by phase flutter at frequencies above 10 kHz will be no greater than grade 1½.

The characteristics of synchronous detector receivers[8] may cause errors in the demodulated video signal level if the signal is phase-modulated at a frequency higher than about 0·5 MHz. However, the restriction to 0·0016 radian peak phase modulation will be more than adequate to prevent any significant impairment from this cause.

The foregoing derivation of curves (a) and (b) is believed to be valid for a phase perturbation at a single frequency but no attempt has been made to assess the effects of two or more simultaneous perturbations. For example, if the offset frequency is at the limit of the long-term average tolerance, then the permissible additional deviation of the offset frequency will be smaller than that shown in Figure 1.

2.2 Sound protection

The protection ratios required for co-channel television transmissions at the frequency offsets normally adopted give adequate protection for the sound signals as well as the picture signals so that the question of additional safeguards for the sound signal in the presence of interference does not arise. However, phase disturbances in the drive unit may affect the sound signal in the absence of co-channel interference.

If the carrier frequency drives for the vision and sound transmitters are separate (either partly or entirely), then any independent phase disturbance in either drive will appear as a phase disturbance in the 6 MHz inter-carrier beat signal which is frequency-demodulated in the sound-channel circuits of domestic receivers. As an example of the audible impairment, the threshold of perceptibility for a 7 kHz continuous tone is about 75 dB below peak programme level. The system peak deviation is ±50 kHz and, taking into account the aural weighting curve (CCIR Rec. 468) and the attenuation caused by the standard 50 μs de-emphasis circuit in the sound channel, the permissible peak frequency deviation is shown by the broken curve in Figure 1(e). If precision offset is employed, the permissible deviation is given by Figure 1(a) or Figure 1(e), whichever has the lower ordinate.

3. Conclusions

For the two cases of long-term frequency stability of transmitters commonly referred to as 'nominal offset' and 'precision offset' conditions, the requirements for short-period stability have been estimated, based partly on available experimental data and partly on calculation.

4. References

1. CCIR XIIIth Plenary Assembly, Geneva 1974. Report 306-2.

2. BROWN, A. 1967. Television co-channel interference: PAL transmissions. BBC Research Department Report No. 1967/62.

3. BROWN, A. 1968. Television co-channel interference: protection ratio for five-thirds line frequency precision offset of carriers with moving pictures. BBC Research Department Report No. 1968/21.

4. HOPF, H. 1958. Experiments on the operation of television transmitters with precision offset carrier frequencies, Rundfunktechnische Mitteilungen, 1958, **2**, 6. pp. 256–276.

5. CCIR Doc. 11/94 (France) Period 1970–1973.

6. KELLER, A. 1972. Synthétiseur d'emetteur: modulation de fréquence de la proteuse image admissible dans le cas du décalage de précision. Etude 17903/A/72, ORTF, January 1972.

7. PAGE, H. 1970. Minimising co-channel interference in television reception. Electronics Letters. 1970, **6**, 15.

8. HARVEY, R.V. 1970. UHF Television: impairments to domestic reception with envelope and synchronous detectors caused by carrier phase perturbations in relay transmitters. BBC Research Department Report No. 1974/5.

Appendix 1

Calculation of tolerance for fluctuations at frequencies between 25 Hz and 10 kHz

In a precision-offset interference situation, visible effects are reduced because the striped patterns are interlaced on alternate fields. If, now, either of the two vision carriers involved are phase-modulated at a modulation frequency exactly equal to the field frequency (25 Hz) or to an odd harmonic of the field frequency, alternate fields will contain, over part of the picture, interference patterns which are displaced in opposite directions and so a stationary pattern will reappear. This stationary pattern is easily visible at a low level and if we make some assumptions about the way in which the protection ratio required for the precision-best pattern is increased by the presence of the stationary pattern, then we can calculate the phase deviation which will give rise to a 1 dB increase in the protection ratio. The increase in the protection ratio can be described by the expression $p^a + q^a = r^a$, where p and q are the protection ratios in voltage terms required for the two interference patterns separately (i.e. the precision-best pattern and the stationary pattern), r is the protection ratio required for the combination of the two and a is an exponent representing the law of addition, such that $a = 1$ for linear addition and 2 for square-law addition.

From the foregoing, we can calculate the values of a that correspond to the two different levels of permissible phase modulation, 0·06 radian and 0·2 radian, given in curves (c) and (d). In making this calculation, we must bear in mind that the amplitude of the stationary pattern must be between 8 and 14 dB (say 11 dB) below that of the precision-best pattern which requires the same protectio ratio and that it will be proportional to the sine of the phase displacement when the latter is small. Thus, the permissible values of phase deviation given by curves (c) and (d) of 0·06 radian and 0·2 radian respectively, yield stationary pattern amplitudes that are 24·6 dB and 14 dB below that for the 'precision worst' condition and hence protection ratios that are 13·6 dB and 3 dB respectively below that for precision best.

Normalising to $p = 1$, the values of a that correspond to the conditions for curves (c) and (d) are given by the following:–

for curve (c), $1 + 0{\cdot}21^a = 1{\cdot}12^a$ or $a = 1{\cdot}2$
and for curve (d), $1 + 0{\cdot}71^a = 1{\cdot}12^a$ or $a = 2{\cdot}8$

For the summation of two different interference patterns of this type which are related coherently, the value of $a = 1{\cdot}2$, i.e. a very nearly linear addition, is thought to be much more likely than $a = 2{\cdot}8$. Hence the central portion of the suggested limit curve has been drawn to coincide with curve (c).

Appendix 2

Calculation of tolerance for fluctuations at 10 kHz and above

The calculation of the permissible frequency modulation or phase modulation of the carrier drive at modulation frequencies of 10 kHz and higher is based on a consideration of the asymmetry of the f.m. sidebands after passing through the vestigial sideband response of a television receiver. This asymmetry causes amplitude modulation of the carrier. The picture impairment produced by this amplitude modulation may be equated with the impairment caused by an interfering signal at a frequency which differs from the vision carrier frequency by the frequency of the unwanted phase or frequency modulation.

In order to equate these two impairments, an allowance must be made for the fact that the amplitude of the video-frequency component caused by the unwanted modulation process is proportional to the vision carrier amplitude whereas that caused by an added c.w. interference is independent of the vision carrier amplitude. It is assumed, taking into account both the magnitude of the unwanted modulation component and its visibility against the background, that it will have the greatest effect on the picture signal in dark grey areas of the picture where the vision carrier amplitude is about 70% of the peak sync level. The permissible modulation depth is therefore about 1·4 times (3 dB higher than) the ratio of permissible interference level to the peak sync carrier level. The permissible c.w. interference level is assumed, for this purpose to be 15 dB lower than the CCIR levels[1] acceptable for 1 to 10% of the time for planning purposes. The limiting modulation depth may therefore be taken at 12 dB below the CCIR levels, leading to a ratio of –62 dB, ignoring the relaxations below 100 kHz and above 1 MHz which are allowed by the CCIR protection ratio curve.

Consider the vestigial-sideband filter response of an ideal television receiver, which rises linearly from zero at $f_o - f'$ through 0·5 at f_o to 1·0 at $f_o + f'$, where f_o is the vision carrier frequency. Let the vision carrier have unit amplitude and be sinusoidally phase-modulated at a frequency f with a peak phase deviation of $\Delta\phi$ radian ($\ll 1$) corresponding to a peak frequency deviation of $\Delta f = f\,\Delta\phi$.

The asymmetrical response of the filter to the carrier sidebands at $f_o - f$ and $f_o + f$ can be regarded as converting them into a pair of quadrature sidebands with identical amplitudes plus an additional signal at the upper sideband frequency $f_o + f$ with an amplitude, after filtering of

$$\tfrac{1}{2}\,\Delta\phi\,\frac{f}{f'}, \quad 0 < f < f'.$$

Since the attenuation of the filter at frequency $f_o + f$ is

$$2f' / (f' + f), \quad 0 < f < f',$$

the amplitude of an interfering signal which, when added to the carrier before the v.s.b. filter, produces the same effect as the phase modulation, will be

$$f\,\Delta\phi / (f' + f) = \Delta f / (f' + f), \quad 0 < f < f'$$

When $f \geqslant f'$, the lower sideband will be zero and the equivalent interfering signal level becomes $\tfrac{1}{2}\,\Delta\phi$. With the ideal v.s.b. receiver response for television Standard I, $f' = 1{\cdot}25$ MHz; however, there is evidence that in the majority of UK receivers the vestigial flank is somewhat steeper than the ideal. For the purposes of this report, it has been assumed that $f' = 1$ MHz. Thus, at modulation frequencies of 1 MHz and higher, we may equate this level with the level of –62 dB as explained earlier in this Appendix, leading to a constant phase modulation limit of

$$\Delta\phi = 0{\cdot}0016 \text{ radian} \qquad f \geqslant 1 \text{ MHz}.$$

When $f \ll f'$, the equivalent interfering signal level becomes approximately $\Delta f/f'$ so that, taking a typical value of f' of 1 MHz, we equate this level with the level of –62 dB as explained earlier, leading to a frequency deviation limit of

$$\Delta f = 800 \text{ Hz} \qquad f \leqslant 1 \text{ MHz}$$

As f approaches 1 MHz, Δf becomes proportional to f, as shown above and in Figure 1.

CLA/JUC

Printed by BBC Research Department, Kingswood Warren, Tadworth, Surrey